Obesity Surgery (2019) 29:3149–3153
https://doi.org/10.1007/s11695-019-03921-5

ORIGINAL CONTRIBUTIONS

Variability of Length of Small Intestine in Indian Population and Its Correlation with Type 2 Diabetes Mellitus and Obesity

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Published online: 14 May 2019

Abstract

Purpose Previous studies have correlated small intestinal length with gender, age, weight, height and ethnic background. Some studies have reported a positive correlation of small intestinal length to body mass index (BMI). Some studies have shown that bypassing proximal small intestine can result in diabetes mellitus (DM) control. Present study was conducted to find correlation of small intestinal length with BMI and DM.

Materials and Methods Two hundred eighty-three patients aged between 18 and 60 years who underwent open or laparoscopic abdominal surgery were included. Height, weight, BMI, random blood sugar (RBS), HbA1c, etc. were noted. A standard 30-cm umbilical tape with 10 cm marking was used to measure the length of small intestine in laparotomy patients, whereas lap bowel graspers with marking of 10 cm on the shaft was used for laparoscopy patients. Statistical significance of normally distributed continuous variables was tested using independent sample *t* test. Spearman rank correlation was used to test association between two ranked variables.

Results The mean small intestinal length in Indian population was 777.1 cm with a standard deviation of 186.2 cm. Mean length of small intestine was significantly higher in patients who had HbA1c ≥ 6.5% and RBS levels ≥ 200 mg/dL. HbA1c and RBS showed significant but a weak positive correlation with length of small intestine. BMI did not show significant correlation with length of small intestine.

Conclusion Small intestinal length had significant but a weak positive correlation in patients who had HbA1c ≥ 6.5% and RBS levels ≥ 200 mg/dL.

Keywords Small intestine length · HbA1c · Random blood sugar · Body mass index

Introduction

The length of the small intestine varies from 3 to 8.5 m. The average length is considered to be approximately 5 m [1]. The variation in the intestinal length in humans is a topic of interest. Differences in measurement techniques, small study groups, and large inter-individual variation have contributed to the uncertainty associated with defining a normal range of intestinal length. Estimation of small bowel length is relevant for many years to plan small bowel resections as the development of malabsorption is closely related to the total length of small intestine that remains after surgery [2]. Despite its great importance in surgical approaches, little definitive information is available on human gut tract length in Indian population. Previous studies have correlated small bowel length with various measures like sex, age, weight, height and ethnic background. Better knowledge of these relationships may aid in avoidance of surgical complications [3].

Overweight and obesity are defined as abnormal or excessive fat accumulation that may impair health. It is currently estimated that nearly 1.9 billion adults worldwide are overweight (body mass index [BMI] ≥ 25 kg/m^2) and a further estimated 600 million are obese (BMI ≥ 30 kg/m^2) according to WHO [4]. India is third in the list of obesity with 30 million obese people. It is well known that being overweight or obese carries an increased risk of type 2 diabetes mellitus (DM),

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cardiovascular diseases, osteoarthritis, sleep apnoea and some malignancies (endometrial, breast and colon) [5, 6]. Some studies have reported a positive correlation of small intestinal length to obesity/BMI [7, 8].

Type 2 DM is a chronic disease with increasing worldwide prevalence. It poses a huge burden on healthcare systems, especially in developing countries [9]. Some studies have shown that bypassing the proximal small intestine can result in DM control [10].

The primary function of small bowel is digestion and absorption of dietary components after they leave the stomach. The enlarged surface area of small intestine enables complete digestion of food stuffs. The major small bowel hormones implicated in appetite control are peptide YY (PYY) and glucagon-like peptide 1 (GLP-1). Both these hormones are released together following a meal to mediate postprandial satiety [10]. Malabsorptive bariatric procedures like Roux-En-Y gastric bypass and bilio-pancreatic diversion suggest that expedited delivery of nutrients to distal ileum can lead to stimulation of hormones called "incretins" mainly GLP and PYY and have favourable impact on DM and obesity. However, it is not known whether a difference in small bowel length could contribute to difference in incretin in the population [11, 12].The primary objectives of the present research was to study correlation of small intestinal length to obesity (BMI) and type 2 DM, whereas secondary objective was to measure and evaluate variability of total small intestinal length in Indian population.

Materials and Methods

Two hundred eighty-three Indian patients aged between 18 and 60 years and both sexes who underwent open or laparoscopic abdominal surgery between April 2016 and November 2017 and ready to participate were included after explaining potential advantages and risks. Permission was obtained from ethics committee and scientific advisory committee of the institution. Exclusion criteria were patients who have had previous small bowel resection surgery, patients undergoing laparotomy or laparoscopy where small bowel length would be affected by other pathology, acute surgical emergencies, hemodynamically unstable patients and patients who had adhesions. Written informed consent was taken from all the patients included in this cross-sectional study. Based on a previous study [13], setting an alpha error at 0.05 and power at 80%, sample size of 277 patients was calculated by a formula [14].

Each patient was subjected to detailed clinical history, clinical examination and investigated preoperatively as per study proforma. Total small bowel length was measured intraoperatively; so, also complications if any (serosal injury) were checked intraoperatively.

Patients were given general anaesthesia and placed in supine position. Midline incision was taken and extended as per need of the surgery in laparotomy patients. In laparoscopy patients, pneumoperitoneum was created by Veress needle. Ports were placed according to the need of surgery. Omentum was lifted up, and small bowel was exposed. Ligament of Trietz was traced (duodenojejunal junction). Small bowel length was measured from ligament of Trietz to ileocaecal valve. A standard 30-cm umbilical tape with 10 cm marking was used to measure small bowel in laparotomy patients (Fig.1), whereas lap bowel graspers with marking of 10 cm on the shaft were used for laparoscopy patients (Fig. 2). The measurement was done from antimesenteric border taking care that the bowel was minimally stretched. We have measured moderately stretched intestine in the phase of relaxation. The serosal length was measured as per the standard protocol in major intestinal surgeries [7, 15, 16]. The length of duodenum was not possible to measure in every surgery as it a retroperitonal organ. Hence, the length of duodenum was kept fixed as 25 cm according to standard textbook [1].

Obesity and overweight criteria were according to standard WHO protocol for Asian populations [17]. Patients with BMI < 18.5, $18.5 < 23$, $23 < 25$, $25 < 30$ and ≥ 30 were labelled as underweight, normal weight, overweight, pre-obese and obese respectively. Patients who had HbA1c > 6.5 and random blood glucose (RBS) > 200 mg/dL were labelled as DM per standard American Diabetic Association definition [18].

Data on categorical variables is presented as *n* (% of cases). Data on continuous variables is presented as mean ± standard deviation (SD) across two study groups. Statistical significance of parametric and non-parametric data was tested using independent sample *t* test and Mann–Whitney *U* test respectively. Spearman rank correlation was used to test the association between two ranked variables. *P* values less than 0.05 were considered to be statistically significant. Data was analysed using Statistical Package for Social Sciences (SPSS) Version 20:0 (IBM, USA) for MS Windows.

Fig. 1 Thirty-centimetre umbilical tape with 10 cm marking used in laparotomy

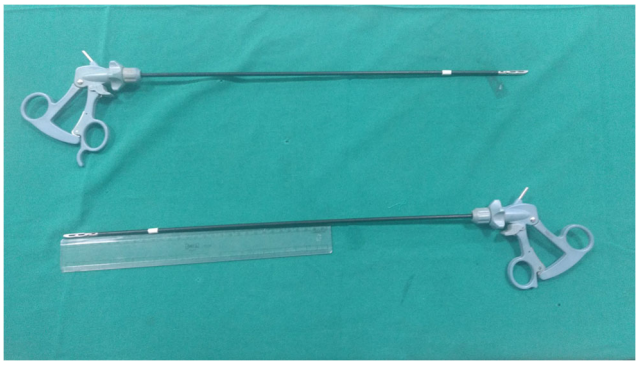

Fig. 2 Graspers marked with 10 cm from the tip used in laparoscopy

Results

We studied variability of the length of small intestine in 283 Indian patients and correlated mean intestinal length with BMI, HbA1c, RBS, height, age and gender. Eight (2.8%), 44 (15.5%), 76 (26.9%), 84 (29.7%) and 71 (25.1%) patients were less than 20 years, 20–29 years, 30–39 years, 40–49 years and 50–60 years respectively. The mean ± SD of age of the patients was 40.9 ± 11.2 years. Out of 283 cases studied, 151 (53.4%) were males and 132 (46.6%) were females. Of 283 patients, 108 underwent laparoscopy, whereas 175 underwent laparotomy. Laproscopy included bariatric surgery and diagnostic laproscopy for abdominal pain. Laparotomy included colonic resection, rectal resection for carcinoma of rectum, splenectomy, radical hysterectomy, Whipple procedure for carcinoma of pancreas, nephrectomy and gastrectomy. The mean length of the small intestine was 777.1 cm with a standard deviation of 186.2 cm. The length of the small intestine varied from 450 cm minimum to 1275 cm maximum.

It is seen from Table 1 that the mean length of small intestine was significantly higher in patients who had HbA1c ≥ 6.5% and RBS levels ≥ 200 mg/dL. There was no statistically significant difference between mean length of intestine and gender and BMI. As depicted in Table 2, age, height and BMI did not show significant correlation with the length of small intestine. HbA1c and RBS showed significant and positive correlation with the length of small intestine.

Discussion

The aim of our study was to measure the variability of the small intestinal length in Indian population and find its correlation with type 2 DM and obesity. We measured the length of small intestine in 283 Indian people who underwent laparoscopic surgery or laparotomy.

Previous studies conducted on living subjects had mean small intestinal length in various ranges. Recent studies by

Table 1 Variability of mean length of small intestine with different variables

Variable	Mean length of small intestine in cm (SD)	*P* value
Gender (*n*)		
Male (151)	791.6 (± 196.7)	0.163
Female (132)	760.6 (± 172.7)	
Body mass index (*n*)		
< 18.5 (6)	740.8 (± 117.9)	0.198
18.5 < 23.0 (45)	743.9 (± 149.8)	
23.0 < 25.0 (39)	805.9 (± 208.9)	
25.0 < 30.0 (111)	759.0 (± 185.9)	
≥ 30.0 (82)	808.8 (± 194.1)	
HbA1c (*n*)		
< 6.5% (168)	751.7 (± 167.6)	0.005
≥ 6.5% (115)	814.2 (± 205.7)	
Random blood sugar (*n*)		
< 200 mg/dL (262)	769.3 (± 177.9)	0.012
≥ 200 mg/dL (21)	874.9 (± 254.5)	

Teitelbaum et al. [15] and Tacchino [16] reported mean small intestinal length of 506 ± 105 cm and 690 ± 93.7 cm respectively. In our study, the mean small intestinal length was 777.1 ± 186.2 cm which is higher than previous studies. This states that small intestinal length was more in Indian population compared to study conducted in other populations.

Backman and Hallberg [7] and Nordgren et al. [19] reported that there was positive and significant ($P < 0.001$) correlation of small intestinal length with BMI, whereas studies conducted by Nassif et.al. [13] ($P = 0.837$) and Guzman et.al. [20] (P value > 0.01) did not find correlation of small intestinal length with BMI. In our study, there was no significant correlation of the length of small intestine and BMI.

There is no reported study previously which compared the small intestinal length and HbA1c either in India or in foreign populations. Many studies have reported resolution of DM after bariatric surgeries. But none of the studies compared small intestinal length and type 2 DM. In our study, patients with HbA1c ≥ 6.5 had a statistically significant (P value =

Table 2 Correlation of different variables with the length of small intestine ($n = 283$)

Correlation of length of small intestine with	*r* value	*P* value
Age (years)	− 0.055	0.356
Height (cm)	0.095	0.112
Body mass index (kg/m^2)	0.086	0.151
HbA1c (%)	0.157	0.008
Random blood sugar (mg/dL)	0.149	0.012

0.008) but a weak positive correlation (r value = 0.157) with the length of the small intestine.

Similarly, not a single study has been conducted previously to compare small intestinal length and RBS in India or in foreign populations. In our study, patients with RBS ≥ 200 mg/dL had a statistically significant (P value = 0.012) but a weak positive correlation (r value = 0.149) with small intestinal length.

Treves [21] stated that mean intestinal length was longer in females (711 cm) than males (686 cm). Similar results were reported by recent study conducted by Hosseinpour and Behdad [22] where mean intestinal length was longer in females (468 cm) than males (459 cm). On the contrary, studies conducted by Nordgren et al. [19] and Teitelbaum et al. [15] reported that males had longer intestinal length than females. In our study in Indian patients, we have found out that males (791.6 cm) had longer intestinal length than females (760.6 cm) but it was not statistically significant.

Studies conducted by Hosseinpour and Behdad [22] and Hounnou et al. [8] reported that there was no significant correlation between height and small intestinal length, whereas Teitelbaum et al. [15] ($P < 0.001$) and Joseph et.al. [23] ($P = .025$) reported a significant relationship between small intestinal length and height. Hounnou et al. [8] reported that there was significant correlation between weight and small intestinal length. In our study, there was no significant correlation between height and weight with the length of small intestine.

There was no significant correlation with age in our study ($P = 0.356$. $r = -0.055$). Teitelbaum [15], Tacchino et al. [16] and Raines et al. [2] also reported the same results.

Limitations

Minor variability in small intestinal length measurement may be present as there is no standard definition to measure small intestinal length at present. Small intestinal length should be ideally measured in the inner mucosal layer to notice the differences under various conditions, but this cannot be done during surgery. The study was aimed to evaluate and measure the small intestinal length and find correlation between small intestinal length and BMI and type 2 DM. Hence, only those parameters are studied. We have not noted the details of medications taken by patients. In case of diabetic patients, we have not noted whether the patients were on oral antidiabetic medicines or insulin. However, effect on antidiabetic medicines or insulin on the length of the small intestine is not reported so far. Characterisations of patients in terms of behaviour and lifestyle were out of the scope of the study design. We have not correlated the length of small intestine with circulating concentrations of specific gut hormones like GLP1, gastric inhibitory polypeptide (GIP) and PYY. Further multi-centric studies on large sample size is recommended to substantiate the findings of our study and correlate the length of small intestine with circulating concentrations of specific gut hormones like GLP1, GIP and PYY.

Conclusions

The mean small intestinal length in Indian patients was 777.1 cm with a standard deviation of 186.2 cm. The mean length of small intestine was significantly higher in patients who had HbA1c ≥ 6.5% and RBS levels ≥ 200 mg/dL. HbA1c and RBS showed significant and positive correlation with the length of small intestine. BMI did not show significant correlation with the length of small intestine.

Compliance with Ethical Standards

Permission was obtained from ethics committee and scientific advisory committee of the institution. Written informed consent was taken from all the patients included in this cross-sectional study.

Conflict of Interest The authors declare that they have no conflict of interest.

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